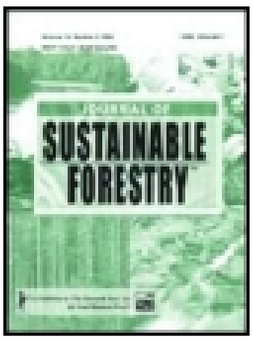

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Determinants of Illegal Logging in Indonesia: An Empirical Analysis for the Period 1996-2010

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Illegal logging is a significant problem in Indonesia, which is one of the few countries with a large forest area. In this paper, we study factors that affect harvesting and supply of illegal timber from Indonesia to China and Japan. We also look at factors that lead to demand of Indonesian illegal timber from China and Japan. A simultaneous-equation econometric model of illegally logged timber demand and supply is developed and tested using annual data over the period 1996-2010. We find that corruption and decentralization in Indonesia have significant and positive impact on illegally logged timber supply while excess demand in Japanese construction and furniture industries as well as Japan's housing starts are significant factors affecting illegal logging in Indonesia. Law enforcement or policies aimed at reducing illegal harvesting in Indonesia are found to be more effective than policies targeting the import of illegal logged timber into Japan and China.

Keywords. Illegal logging in Indonesia; Illegal timber trade; Simultaneous-equation model; Deforestation; Illegal timber demand

INTRODUCTION

Indonesia is the third largest country in terms of tropical forest area and also a country with the second highest deforestation rate (FAO, 2010). Each year, a large area[1] of forest in Indonesia is lost, the majority of which is due to illegal logging. Illegal logging has detrimental effects on the environment, the economy and the society in Indonesia (Obidzinski et al., 2006). The aim of this paper is to study factors that affect illegal harvesting of timber in Indonesia and to evaluate the effectiveness of policies implemented inside as well as outside Indonesia to reduce illegal logging.

The term 'illegal logging' is often used to refer to the cutting of trees in protected forest areas (Callister, 1999; FFPRI, 2005). However, to study the impacts of different policies that aim at reducing illegal logging, it is necessary to extend the notion of illegal logging beyond harvesting activity. For example, a policy that restricts the demand of illegally logged timber may help to reduce the incentive to cut down trees illegally. For this reason, we follow the literature and use the term 'illegal logging' to refer to the entire supply and demand process of illegally logged timber[2] (Brack et al., 2002; IGES, 2007; Luttrell et al., 2011). This latter (more general) definition is especially helpful in studying the determinants and magnitudes of illegal logging in the practical context that Indonesia trades with multiple partners.

Recognizing the serious impacts of illegal logging, Indonesia has implemented a number of policies to control forestry related crimes (Obidzinski et al., 2006). A ban on log exports was implemented for the first time in 1985 by the Indonesian government to promote sustainable harvesting and support the development of the domestic wood processing industry (Gellert, 2003;

[1] About 498 thousand hectares, according to FAO,2010.

[2] For example, in Brack et al., (2002), "Illegal logging takes place when timber is harvested, transported, bought or sold in violation of national laws. The harvesting procedure itself may be illegal, including corrupt means to gain access to forests, extraction without permission or from a protected area, cutting of protected species or extraction of timber in excess of agreed limits. Illegalities may also occur during transport including illegal processing and export, mis-declaration to customs, and avoidance of taxes and other charges".

Luttrell et al., 2011). The ban was lifted in 1997 to alleviate the impact of the Asian financial crisis and was reintroduced in 2001 when the Indonesian economy had recovered. An anti-money laundering law and an anti-corruption law were introduced in 2003 as indirect measures to control forest crimes (Luttrell et al., 2011). Two agencies, the Corruption Eradication Commission and the Financial Intelligence Unit, were set up to monitor the law enforcement by relevant agencies (Dermawan et al., 2011). These law enforcement agencies have been argued to have the potential to control illegal logging through a strategy of "follow the money"[3]. In addition, Indonesia and other wood-producing countries have signed multilateral or bilateral agreements with wood-consuming countries to control illegal logging (Setiono et al., 2005). For example, China and Japan signed Memorandum of Understandings (MoU) with Indonesia to guard against forestry crimes by exchanging information and enhancing cooperation in 2002 and 2003, respectively (Setiono et al., 2005). However, the exact impact of these bilateral agreements has been challenging to ascertain due to lack of reliable statistics (Luttrell et al., 2011). In 2008, the US amended the Lacy Act of 1990 to prohibit importing of illegally sourced plant materials and products, which restricted the export of illegal Indonesian timber products to the US (Prestemon, 2015). Further, in 2013, Indonesia developed a timber legality assurance system, known as SVLK (Sistem Verifikasi Legalitas Kayu), to track the movement of timber from harvesting to trading stages (Luttrell et al., 2011)[4]. This system has been considered as an effective way to curb illegal logging, and also crucial towards Indonesia's successful signing of a Voluntary

[3] For instance, the President Director of Surya Dumai Group, Marthias, was charged with corruption in the forestry sector, while the Governor of East Kalimantan, Suwarna Abdul Fattah, was charged with receiving bribes from Marthias (Luttrell et al., 2011) (Court decision No. 21/PID.B/TPK/2006/PN.JKT.PST on Marthias. Court decision No. 380.K/Pid. Sus/2007 on Suwarna). They were sentenced to 18 months and 4 years in prison separately (Luttrell et al., 2011). Details of the cases please refer to:
http://www.cifor.org/ilea/_pf/1/_ref/indicators/cases/decision/Martias.htm
http://www.cifor.org/ilea/_ref/indicators/cases/decision/suwarna_AF.htm

[4] We would like to thank a referee for pointing out these more recent policies. The impact of these policies is, however, not captured in our dataset, see the limitation section for further details.

Partnership Agreement (VPA)[5] for meeting the requirements of EU Timber Regulation (Luttrell et al., 2011; Obidzinski et al., 2014).

Factors that affect illegal logging in Indonesia have been analysed in previous studies. Dieter (2009) estimates illegal timber trade, using an adjusted input-output model and trading records of multiple countries. International trade is found to increase the supply of illegal timber while ineffective forestry governance is found to be an important factor that facilitates illegal harvesting activities. Contreras-Hermosilla et al. (2008) suggest that effective controlling of illegal logging requires both supply and demand related measures. Harwell et al. (2009) provide a comprehensive report that summarizes illegal logging activities in Indonesia using data collected from fieldwork as well as information acquired from media, government reports and reports from various NGOs (e.g. FAO, ITTO). It is observed that corruption in the forestry sector is a critical factor that drives illegal harvesting and the most common corruption activity takes the form of issuing fake documents that allow companies to clear more trees than they are entitled to. Harwell and Blundell (2009) suggest that to reduce illegal logging and corruption in Indonesia, the forestry management system needs to be improved and the anti-money laundering legislation needs to be augmented with corresponding bank regulations.

In addition to corruption, ill-designed institutions for forest management also contribute to the illegal logging problem. Casson et al. (2002) analyze the problem of illegal logging in Indonesia from the political economy perspective. They suggest that the decentralization process, which assigns substantial forestry management decision making power to local government, encourages illegal logging in Indonesia. As local governments are allowed to issue timber permits, and also to keep district taxes from these permits, they have strong incentives to permit excessive logging (Casson et al., 2002). Logging practices permitted by local governments are observed to be in contradiction with guidelines of sustainable forests development in many cases, and induce the same detrimental impacts as those by 'illegal' logging (Casson et al., 2002). Mismanagement of logging permits at the local government level is found to reduce the impacts

[5] VPA is an essential component of the EU bilateral trade agreements between the EU and its timber exporting partner countries (Obidzinski et al., 2014).

of the forest law enforcement by the central government. Burgess et al. (2012) analyze the effect of decentralization on deforestation (including 'illegal' logging) in Indonesia. They find that by increasing the number of districts, the decentralization process, in fact, has accelerated the deforestation rate. Smith et al. (2003) conduct an analysis by distinguishing between collusive and non-collusive corruption. Collusive corruption is argued to be the main driver of illegal logging in the period that follows the fall of President Suharto.

Determinants of illegal logging in other countries have also been examined in the literature. Alemagi et al. (2010) discuss factors that affect illegal logging in Cameroon, including systemic corruption, poverty, conflicts, licensing society, usurpation of property rights and inadequate institutional support. Hansen et al. (2008) estimate the amount of illegally logged timber in Ghana from 1996 to 2005 using timber export statistics, domestic timber consumption estimates and official harvesting records. Around 70 percent of timber harvested in Ghana is found to be illicit, due largely to policy failure and the lack of effective economic incentives for farmers and local communities to protect forestry (Hansen et al. (2008). In contrast, Nanang (2010) suggest that the main cause of illegal logging in Ghana is the high timber export demand, and to reduce deforestation, policies are implemented to reduce timber export, which then restricts both legal and illegal harvesting. Richards et al. (2003) analyze the social, economic, environmental and governance impacts caused by illegal logging in Honduras and Nicaragua. Besides adversely impacting on the environment, illegal logging is found to hurt the economy as firms that harvest and process legal timber find it difficult to compete with illegal operations. Richards et al. (2003) suggest that to reduce illegal logging, measures curbing corruption and incentive schemes for improving forest management are required. McElwee (2004) examines the problem of illegal logging in Vietnam and finds that creating personal incentives for forest protection and management is an effective method for controlling illegal logging.

Despite the large number of studies on illegal logging, no study has analysed factors driving illegal logging within a multiple market framework using econometric models. The impacts of domestic and bilateral policies have not been formally estimated either. In this study, we develop a simultaneous-equation model to estimate factors that affect illegal logging. The model

incorporates both demand and supply characteristics of logging. We select Japan and China, which are Indonesia's main timber trading partners and also the suspected main illegal timber importers, to represent the demand side of Indonesia's illegal logging. Different from the standard simultaneous-equation model, we analyse the illegal timber demands from Japan and China in two separate sets of equations to allow the incorporation of country specific factors.

In addition, we test the impacts of key policies that were introduced by the Indonesian government to reduce illegal logging activities, including the ban of log exports as well as the anti-money laundering and anti-corruption laws. The effectiveness of forest related policies adopted in importing countries is also examined. We also test the effectiveness of bilateral agreements, which forbid the trade of illegally logged timber, in both the supply and demand equations of our model.

The remainder of the paper is organized as follows. A discussion on the data used for this study is provided in next section, following which, we outline the modelling framework and the testing procedures. Estimation results and policy implications are discussed next. In particular, we first present the results and analysis of factors causing illegal logging, then we discuss the impact of political factors in Indonesia. The impact of the green purchase laws on curbing illegal timber import from Japan are analysed next. We also discuss some key limitations of our approach. The conclusion summarizes the main findings of the paper.

ILLEGAL LOGGING DATA FOR INDONESIA

The complex underground operation of timber smugglers makes it almost impossible to obtain accurate information for quantifying illegal logging and illegal trade. Official statistics may reflect a small portion of illegal logging activities that are discovered, and are therefore not reliable, while most quantitative reports on illegal logging provide estimates based upon 'speculation and anecdotal information' (Burgess et al., 2012). Among frequently cited sources, Palmer (2001) uses a materials balance model to estimate illegal logging by comparing the supply and demand of the round wood in Indonesia. The volumes of illegal logging in Indonesia in 1997 and 1998

were estimated to be 49.176 million m^3 and 64.612 million m^3 of round wood equivalent, respectively. The Indonesian Ministry of Forestry provides estimates of illegal timber supply over the period 1980 to 2005 based on the differences between the official round wood production and consumption in the processed wood industry (Manurung et al., 2007). The highest amount of illegal round wood was estimated at 42.2 million m^3 in 2002 and fell to 20.3 million m^3 in 2005 (Manurung et al., 2007). Harwell et al. (2009) use the difference between legal timber supply and the total timber consumption to estimate the level of illegal timber supply in Indonesia. Their estimates indicate that the level of illegal timber produced in the country over period 2003-2006 is about 30 million m^3 per year (Harwell et al., 2009).

After introduction of the log export ban in the mid-1980s, log exports from Indonesia were reduced significantly while export of other wood products such as plywood, increased rapidly (Makkarennu, 2013). Indonesia became the largest supplier of plywood in 1997. Fig. 1 depicts Indonesian plywood production and exports between 1996 and 2010. It shows that most of the plywood produced in Indonesia (on average 87.60 percent) is exported, and a large proportion (around 40 percent) is exported to Japan and China (Fig. 2). These are the main importers of Indonesian plywood, accounting for around 40 percent of the total plywood exports from Indonesia during the period 1996-2010.

The ITTO (1997-2012) report provides information on the annual timber trade in the world based on the data provided by individual countries. However, for the same trading channel, the quantity reported by the exporting country is often different from the quantity reported by the importing country. For example, in 2002, the export of plywood to Japan was reported by Indonesia to be 1.956 million m^3, while the plywood import from Indonesia was reported by Japan to be 2.637 million m^3, a difference of 0.681 million m^3. Similar discrepancies were also observed between China and Indonesia's trading records. In the report by ITTO (1997-2012), these discrepancies have been attributed to different measurement approaches and timber smuggling.

The gap between Japan's timber imports from Indonesia and Indonesia's timber exports to Japan is presented in Fig.3. An account of similar discrepancies in timber trade between China

and Indonesia[6] is presented in Fig.4. The unexplained gaps increase after 1998 in Fig.4 and after 1999 in Fig.3, peak in 2001 and decline thereafter in both Fig. 3 and 4. If these gaps are due purely to different measurement approaches used by different countries, the gaps between trading records should be constant over time. In terms of the fluctuations in gaps observed in Fig.3 and Fig.4, a possible explanation could be the ongoing trade in illegal timber. It is apparent from Fig.3 and Fig.4 that most of the recorded timber trade in the importing countries, Japan and China, are higher than the recorded exports from Indonesia. It seems that Indonesia under-reports the actual trade records, which consistently exceed the annual forest harvesting concessions issued by the government. In addition, the annual discrepancies observed between Japan and Indonesia, and China and Indonesia have a similar trend (they both increase from 1998 and decline after peaking in year 2001) (see Fig.5). This is also consistent with illegal logging estimates generated by previous studies, such as Manurung et al. (2007), Harwell et al. (2009) and Lawson et al. (2010). Given that our focus in this study is on two of Indonesia's major timber trading partners, Japan and China, using illegal values based upon the annual discrepancies (in export and import records) offers a novel way to estimate the illegal timber volumes, as compared to relying on overall illegal logging amount that includes all of Indonesia's trading partners. Therefore, in this study, we use the discrepancies in the trading records between Japan and Indonesia, and China and Indonesia as proxies for the export of illegally logged timber from Indonesia (see Fig.5)[7].

[6]The timber trading records include trading of log, swan timer, veneer and plywood. These wood products were converted to the log equivalent by index of logs 1:1, swan timber 1:1.43, veneer 1:1.9, plywood 1:2 (Hou et al., 2011).

[7] Other main timber importing countries of Indonesia are UK and US. Around twenty percent of Indonesian plywood was exported to these two countries (ITTO 1997-2012). However, they were not selected as the main illegal timber importers as their estimated amount of illegal timber imports are not significant. Appendix B presents discrepancies in the trading records between US and Indonesia, and UK and Indonesia between 1996 and 2010.

MODELLING FRAMEWORK

The Simultaneous-Equation System Model

In a single-equation model, the dependent variable is expressed as a linear function of one or more explanatory variables (Gujarati, 2003). However, when a two-way flow of influence among variables is present (for instance, Y is determined by the X, and X is, in turn, determined by Y), a simultaneous-equation system comprising two or more equations is required (Gujarati, 2003). In this study, the price and the quantity of illegal logging are determined by the intersection of the demand and supply curves. Considering this simultaneous relationship, a simultaneous-equation model including a supply function, two demand functions and an equilibrium condition function was required: the demand for Indonesian illegally logged timber (proxied by the total demand of Indonesian illegal timber by Japan and China) depends on legal timber price and economic conditions of the importing countries, while the supply of Indonesian illegally logged timber depends on the timber price and the economic and policy environments in Indonesia.

Chinese demand for Indonesian illegal timber (Q_C) is modelled to depend on Indonesian timber price (*P*), the number of new housing starts (HS_C) and the log production in China ($PLOG_C$):

$$\log(Q_C) = \beta_{10} + \beta_{11}\log(P) + \beta_{12}\log(HS_C) + \beta_{13}\log(PLOG_C) + \eta_C \quad (1)$$

In several studies, illegal timber import is argued to be an important source of input for the booming China economy (EIA&Telapak, 2005; Robbins et al., 2012). Variables such as the number of new housing starts (HS_C) is expected to positively influence the illegal timber demand from China, while the domestic production of round log ($PLOG_C$) is expected to have a negative coefficient.

Japanese demand for Indonesian illegal timber (Q_J) is similarly modelled to depend on Indonesian timber export price (*P*), the domestic production of round log ($PLOG_J$) and the number of new housing starts (HS_J) in Japan:

$$\log(Q_J) = \beta_{20} + \beta_{21}\log(P) + \beta_{22}\log(HS_J) + \beta_{23}\log(PLOG_J) + \eta_J \quad (2)$$

Japanese domestic production of timber products has decreased since the early 1990s due to recession and a tariff reduction after trade liberalization (Araya et al., 2008). Environmental concerns also led to a decline in the domestic wood production. As a result of the reduction in domestic supply, demand for imported timber, including illegal timber from Indonesia, increased. Therefore, the domestic production of round log in Japan ($PLOG_J$) is expected to have a negative impact on the illegal timber demand. The number of new housing starts variable (HS_J) is expected to positively influence the illegal timber demand from Indonesia.

Indonesian illegal timber supply (Q_I) is modelled to depend on Indonesian timber export price (*P*), the increase in the number of districts in Indonesia ($INDIS_I$), Indonesian GDP (GDP_I), Indonesian corruption index (CI_I) and the percentage of paved road out of the total road in Indonesia ($PROAD_I$):

$$\log(Q_I) = \beta_{30} + \beta_{31}\log(P) + \beta_{32}\log(INDIS_I) + \beta_{33}\log(GDP_I) + \beta_{34}\log(CI_I) + \beta_{35}\log(PROAD_I) + \eta_I \quad (3)$$

The choice of explanatory variables in Equation (3) is based on the analysis of previous studies. As discussed in Casson et al. (2002), Indonesia embarked on the path of decentralized governance since 1998, leading to the addition of several new districts. Since the heads of these districts are allowed to issue small-scale forest clearing concessions to companies, increasing the number of districts may lead to an increase in forest clearance. The increasing number of districts has been argued by Burgess et al. (2012) to accelerate the level of unsustainable

harvesting in Indonesia. In addition, corruption has been seen as a culture at the top government levels during the last thirty two years of governance by the ex-president Suharto (Palmer, 2001). This culture has gradually spread over to the sub-national governments. Changes in corruption perception index of Indonesia may therefore exhibit potential correlations with illegal logging activities. Since the road network and road building were considered as key factors relating to the transportation costs for forest harvesting and timber supply (Brown et al., 1994; Merry et al., 2009), the percentage of paved road out of the total road in Indonesia was included in the supply equation. This variable may have positive effects on illegal timber supply as road paving has been argued to exacerbate deforestation through logging and fire in Amazon forests (Kirby et al., 2006; Nepstad et al., 2001).

The model is completed with a fourth equation that states the market equilibrium condition (Indonesian illegal timber supply (Q_I) equals the sum of Chinese demand for Indonesian illegal timber (Q_C) and Japanese demand for Indonesian illegal timber (Q_J)):

$$Q_I = Q_C + Q_J \tag{4}$$

To investigate the impacts of different policies, we use dummy variables that take the value of 1 when a policy is in place and 0 when it is not. The dummy variable, *REGU*, represents the ban on log exports, which is aimed at stopping round log exports and promoting sustainable harvesting in Indonesia (Gellert, 2003; Luttrell et al., 2011). The dummy variable *ANTIM* represents the anti-money laundering law and anti-corruption law. These laws were argued to contribute significantly towards curbing illegal logging in Indonesia (Luttrell et al., 2011). The dummy variable, *BIL*, represents the bilateral agreements between Indonesia and its main timber importing partners (including UK, the US, Malaysia, China and Japan) to restrain the trading of illegal timber beyond Indonesian borders.

The model is estimated using annual data over the period 1996-2010. There are a number of unique features of the model in terms of the selection of explanatory variables that differentiate it from previous studies. The variable relating to Indonesian corruption index (CI_I) has only

been qualitatively analysed in previous studies of Indonesian illegal logging (such as those by Smith et al. (2003), Harwell et al. (2009), Dermawan et al. (2011) and Downs et al. (2012)). None of the previous studies has included the Indonesian corruption index (CI_I) in an econometric model to test its impact on illegal logging supply in Indonesia. Addtionaly, the total number of districts in Indonesia has been increasing over time, which has led to an increase in harveting quotas. While number of districts has been used previsouly for testing its impact on deforestation in Indonesia in a study by Burgess et al. (2012), no econometric analysis exists thus far to directly test for its effects on illegal logging supply. Similarly, some other key variables such as the percentage of paved road in Indonesia, the number of new housing starts and the domestic production of round log in Japan and China have been used to analyse their impact on deforestation, however, their role in explaining illegal logging in Indonesia has not been explicitly explored. Further descriptions and data sources for these variables are presented in Appendix A.

Estimation of the Two Stage Least Square Model

With a simultaneous-equation model, applying the Ordinary Least Square (OLS) method to each demand and supply equation of the model will result in inconsistent estimates. This is due to the correlation between price (*P*) and the error terms in demand and supply equations (Greene, 2003). The model can be consistently estimated using the Two Stage Least Square (TSLS) method. In the first stage, an instrumental variable called *predicted P*, which is highly related to *P* but unrelated to the error terms is estimated. In the second stage, the endogenous variable, *P*, is replaced by *predicted P* obtained from the first stage. Equations that use *predicted P*, instead of *P*, can be estimated using the OLS.

To estimate the instrumental variable in the first stage, $\log(P)$ is regressed on all exogenous variables in the model as in equation (5).

$$\log(P) = \theta_0 + \theta_1 \log(HS_C) + \theta_2 \log(PLOG_C) + \theta_3 \log(HS_J) + \theta_4 \log(PLOG_J) + \theta_5 \log(INDIS_I) + \theta_5 \log(CI_I) + \theta_6 \log(GDP_I) + \theta_7 \log(PROAD_I) + \pi \quad (5)$$

The predicted value of $\log(P)$ based on the OLS estimates in (5) is then used as the instrumental variable (*predicted P*).

In the second stage, the endogenous variable, $\log(P)$, is replaced by *predicted P* in Equations (1), (2) and (3). Each of these equations is then estimated using an OLS regression. As explained above, the regression of TSLS can be done step by step manually. However, several software packages offer an easier way to perform it automatically. We estimate the model using Gretl software [8](Cottrell, 2001).

Tests for Appropriateness of the Instrumental Variable

Tests are conducted to determine if TSLS is required and whether the instrumental variable helps overcome the inconsistency problem when TSLS is used. TSLS may help overcome the inconsistency problem but increases the variances of estimators at the same time. This is because the instrumental variable is just an estimate of the endogenous variable ($\log(P)$) and is not perfectly correlated with the endogenous variable. To determine whether TSLS is required, the Hausman test is conducted when the endogenous variable ($\log(P)$) (rather than the instrumental variable) is used in the demand and supply equations to test the correlation between the endogenous variable and disturbances. The null hypothesis of the Hausman test is that no correlation exists (Greene, 2003). The null hypothesis cannot be accepted when the P value of the test results is or lower than 0.1. TSLS is then required for the model.

To test the validity of the instrumental variable in the TSLS model, we use Sargan test to determine whether the instrumental variables are correlated with disturbances and the weak instrument test to determine whether the instrumental variables contain sufficient information from the original endogenous variable to be relevant. The null hypothesis of Sargan test is that all instrumental variables are valid (Gujarati, 2003). If the P values are larger than 0.1, the null hypothesis can be accepted. The weak instrument problem can be tested using the F-statistics of

[8] Details related to Gretl Software can be found at the website: http://gretl.sourceforge.net/

the first stage of the TSLS (Bound et al., 1995; Stock et al., 2002). A value larger than ten implies a good fit without the weak instruments problem (Cottrell et al., 2012). The F-statistics of the first stage of the TSLS are presented in the third to last row of Table 1, and are all higher than ten.

Test results, as shown in Table 1, demonstrate that TSLS method performs well in this model except for the Hausman test and Sargan test in the equations estimating China's demand and Japan's demand. The P values of the Hausman test indicate that the OLS is consistent in the Chinese and Japanese demand function. The Sargan test of the functions suggests that the instruments are invalid. Therefore, the China and Japan' demand functions were regressed separately using OLS. The results are also presented in the Table 1. However, the differences between results under TSLS and under OLS for the Japan and China's demands turn out to be insignificant.

ESTIMATION OF RESULTS AND DISCUSSION

Analysis of Factors Causing Illegal Logging

The estimation results are provided in Table 1. Since all variables are log transformed, the estimated model is a double log model. As such, the coefficient of an explanatory variable is the elasticity of the dependent variable with respect to a change in that explanatory variable. The estimation results indicate that the increase in the number of districts ($INDIS_I$) has a negative and significant effect on the illegal timber supply from Indonesia. An increase in the number of $INDIS_I$, by design, leads to more logging rights, and increases the area of legally harvested forest. With a reduction in total area of forest available for harvesting and everything else staying the same, illegal logging would decline. However, some logging practices permitted by local governments might be considered as 'illegal' by the central government (Casson et al., 2002). That is because the district governments have issued permits for forest clearing activities without considering the sustainability of the forest. Consequently, even if the logging activities permitted by district

governments are legal, the amount of forests harvested increases despite a reduction in illegal logging.

The coefficient of CI_I is negative and highly significant, suggesting that higher level of corruption is positively correlated with illegal logging. Note that CI_I is a corruption perception index that takes a lower value when corruption is high. This finding is consistent with the findings by Palmer (2001) and Downs et al. (2012), that corruption is a key driver of accelerating harvesting and trading in illegal timber. Most illegal and corrupt activities related to timber trade, such as harvesting, delivery and making forged documents, happen in Indonesia rather than in the importing countries. In the model presented here, introducing a variable relating to the corruption index in Indonesia is much more meaningful than including the corruption perception index of importing countries (the corruption perception indices for Japan and China were tested in the model, but they emerged as insignificant).

As expected, the percentage of paved roads in the total road length in Indonesia ($PROAD_I$) shows a positive and significant coefficient. A good road network reduces the transportation costs for delivering round-log from the harvest locations to the milling centre and to the ports. The increasing percentage of paved roads in Indonesia plays a positive effect in promoting illegal timber export by reducing transportation costs.

The third and fourth columns in Table 1 present the estimates of illegal timber demand in Japan. The number of new houses (HS_J) has a positive and significant coefficient. The use of wood in buildings is considered as a part of Japanese culture and tradition. Wood and wood products used in the construction industry accounted for a large proportion (40 percent) of the total wood demand in Japan (MAFF, 2010). In a traditional house, about 0.2 m^3 of wood is required for each squared meter of non-structural area (MAFF, 2010). However, most of the wood (80 percent) used in construction is imported (MAFF, 2010). Therefore, the number of new housing starts plays an important role in influencing the import of wood and that of the illegal timber.

As expected, domestic wood production ($PLOG_J$) in Japan has a negative and significant impact on Japanese demand for illegally logged timber import from Indonesia. As shown in Fig.6, the domestic timber self-sufficiency rate in Japan fell in the beginning of the 1990s and rose back after 2003. The rate in 2007 was 23 percent which is similar to the rate (25 percent) in 1991. During the time period from 1992 to 2007, the domestic timber self-sufficiency rate was lower than 25 percent. This meant that Japan's domestic wood supply was insufficient, and this, in turn, led to a higher demand for illegal timber from Indonesia (the impact of Japan's GDP on illegal timber demand was also tested in the model, however, it emerged as insignificant).

The last two columns in Table 1 present the estimates for illegal timber demand in China. Domestic wood production ($PLOG_C$) in China has a negative and significant impact on illegal timber import. Fig.7 illustrates round log production figures in China from 1996 to 2010. As shown in Fig.7, the production of round log declined since 1998. China's Natural Forest Protection Programme was also implemented in 1998. This Programme was aimed at controlling the resource crisis in the national forest areas and preventing environmental degradation (Witness, 2009). Timber harvesting for commercial purposes was halted completely in the upper Yangtze River and also in the middle and upper reaches of the Yellow River. Commercial logging was also sharply reduced in the Northeast and Inner Mongolia. This Programme contributed a great deal towards the protection of China's forests. The natural forest cover increased by 393.05 million m^3 within the last ten years, as indicated by comparisons between the 6^{th} and 7^{th} national forest resources inventory (Cao et al., 2011). In the meanwhile, the number of reforestation and afforestation projects have significantly increased in China. In 2000, the reforested area was around 46,000 hectares, including 4,000 hectares of fast-growing forests (Liu et al., 2000). After the log production hit a low in 2002, production has increased as a result of the reforestation projects leading to additional harvesting options. The fluctuations in domestic wood supply have had significant effects on the timber imports demands. With a decrease in the domestic wood supply, domestic consumption has increasingly relied on imports. This has also added to the demand for illegal timber, especially for the tropical wood from Indonesia. However, whenever the domestic wood supply has increased, the illegal timber demand has declined.

One crucial aspect that we have not included in our analysis is related to the impact of palm oil prices on illegal logging. One would expect that as palm oil prices increased, the tendency to clear forest would increase as well. However, between 1990 and 2005, nearly half of oil palm expansion occurred through conversion of cropland area (Koh et al., 2008) and oil palm was often planted in the area previously degraded by fire and logging (Fitzherbert et al., 2008). The effect of palm oil expansion on deforestation has been discussed in a number of studies in the past (Abood et al., 2015; Fitzherbert et al., 2008; Sandker et al., 2007). However, it has not been possible to find a quantitative linkage between palm oil expansion and illegal logging in Indonesia. In this paper, we included the variables concerning palm oil price[9], palm kernel oil price[10] and Indonesian palm oil production[11] to test for their impact on illegal logging. However, these variables had to be dropped as they turned out to be insignificant and of wrong sign. Moreover, they were also found to be correlated with a key variable in our model, namely the Indonesian corruption index.

Impact of Policies to Mitigate Illegal Logging

The impacts of various policies are examined by including a dummy variable that represents the introduction of a particular policy in the illegal logging supply equation. The studied policies include a ban on log exports (*REGU*), the anti-money laundering and anti-corruption law of 2005 (*ANTIM*) and the bilateral agreements with timber-importing countries enacted in 2002 (*BIL*). Since the correlation coefficients between CI_I and the regulation related dummy variables, as well as between $INDIS_I$ and the dummy variables, are higher than 0.5, the variables CI_I, $INDIS_I$ were dropped from these regressions to avoid potential multi-collinearity issues. The estimated results are described in Table 2.

[9] Source: World Bank Commodities Price Data

[10] Source: World Bank Commodities Price Data

[11] Source: United States Department of Agriculture https://pecad.fas.usda.gov/highlights/2015/12/Indonesia/Index.htm

The results of the regression including *REGU* as a variable are presented in the third column of Table 2. The coefficient for REGU is significant and negative, which means that the total illegal supply has dropped since the implementation of the log export ban. This could also be confirmed through the Indonesian log trading records from ITTO (1997-2012). The trading records of Indonesian log exports to China and Japan, and Chinese and Japanese log imports from Indonesia show a significant drop when the log exports ban was reintroduced in 2001 (see Fig.8 and 9). Note that log is not the only product included in the definition of timber export recorded by Indonesia or timber import recorded by China and Japan. Other products include veneer, plywood and sawn timber. Burgess et al. (2012) have suggested that after the ban of log export, illegal as well as legal logs are transformed into processed products such as plywood before being exported, and the effectiveness of the log export ban in reducing illegal logging is doubtful. This view may be supported by the ITTO (1997-2012) report as well, which suggests that the amount of log exported by Indonesia has declined significantly, while at the same time, Indonesia has been the largest exporting country for plywood since 1997. However, since the definition of illegal logging includes log as well as other products, our results suggest that the ban of log export is actually effective in reducing illegal logging, even after the effect of product transformation is taken into account.

The coefficient of *ANTIM* (anti-money laundering and anti-corruption laws) is negative and significant (in the fourth column of Table 2). Since corruption is a key driver of illegal harvesting, the laws and related policies are effective in curbing illegal logging by catching the grey money and preventing corruption. Controlling corruption will also provide a climate for designing and implementing other policy instruments to reduce illegal logging (Amacher, 2006).

The regression results incorporating the bilateral agreements (*BIL*) are presented in the last column of Table 2. Note that the coefficient for *BIL* is also negative and significant. Illegal logging is an activity that involves several parties and countries. Curbing illegal logging needs the cooperation of all countries involved. The estimates of their effects on timber-importing countries will be discussed in the next section.

The Green Purchase Law in Japan

The Green Purchasing Law was introduced in Japan to promote the consumption of eco-friendly goods and services by the states and other entities. The item 'legal wood' was added in the Green Purchasing Law by the Japanese government after the issue of illegal logging was discussed at G8 Summit in 2005 (MOE, 2007). Based on this law, the wood and wood products need to be verified for their legality and sustainability before being imported to Japan (MOE, 2007). Meanwhile, methods, such as tracing timber source, using satellite data and cooperating with related countries, were developed by the Japanese government to deal with illegal logging (MOE, 2007). Table 3 presents the regression results using the Green Purchasing Law (GREENJ) as a dummy variable. The variable of $GREEN_J$ has a negative and significant coefficient, which means the law has had a positive effect on reducing the import of illegal timber.

In addition, the tests for bilateral agreements (*BIL*) in Japan's and China's demand models are presented in Table 3. Such agreements, especially involving several parties, however, have had limited effects. The limited effect in the case of China have been attributed to the fact that the MoU was signed with the Chinese State Forest Administration, which is only responsible for domestic forestry issues (Jurgens, 2006). This agreement could become more effective if the China Customs Agency, which is responsible for the screening of imported goods, can get involved in the future (Jurgens, 2006).

Finally, it is also worth testing whether the global financial crisis (in 2007-2008) had any impact on illegal timber demand or supply. A dummy variable, (which took the value of 1 for the period 2007-2008 and 0 in others years) reflecting the potential effects of the global financial crisis of 2007 and 2008, was added to the model. However, the variable turned out to be insignificant.

LIMITATIONS OF THE STUDY

Our study has a number of limitations in terms of data and methodology, which are worth mentioning. First, as no official statistics of illegal logging could be found, we estimated Indonesian illegal logging on the basis of the trading discrepancies between Indonesia and its main importing partner countries. Although the accuracy of the data could not be guaranteed, the annual discrepancies between Japan and Indonesia, and China and Indonesia have a similar trend (they both increase since 1998 and decline after peaking in year 2001), which is also consistent with illegal logging tendencies estimated by previous studies, such as Manurung et al. (2007), Harwell et al. (2009) and Lawson et al. (2010). Second, except for Japan and China, other Indonesian timber importing countries and associated policies were not considered in this paper. The UK and the US are important timber trading partners of Indonesia and are also suspected of importing Indonesian illegal logging. However, they were not selected in this study due to lack of credible data (that is, their timber trading discrepancies were not found to be significant). Third, some key policies for curbing illegal logging, such as the EU FLEGT VPA process, the SVLK and the US Lacey Act Timber Amendments in 2008, were not considered in this paper as they are beyond the time period of the study (1996 to 2010) and also because they do not have a direct impact on curbing illegal logging trading between Indonesia and Japan, or between Indonesia and China.

CONCLUDING REMARKS

In this paper, we develop a simultaneous-equations model to estimate the impact of various factors that affect illegal harvesting and trading of timber in Indonesia. The model is estimated using annual data for the period 1996-2010. We estimate the determinants of illegally logged timber demand from Japan and China as well as the supply of illegal timber from Indonesia. For

modelling illegally logged timber supply, the key explanatory variables used in our study include the number of new districts created in Indonesia during the period of analysis, corruption index as well as related policies, such as Indonesian log exports ban, Indonesian anti-money laundering and anti-corruption laws and the various bilateral agreements between timber trading countries. For estimating the demand for illegally logged timber, we include the excess demand for timber as well as the number of new housing constructions in the importing countries.

The main findings of this study can be summarized as follows. On the supply side, corruption in Indonesia has a significant impact on the supply of illegally logged timber. In addition, the increase in forest extraction permissions resulting from an increase in the number of districts may merely disguise 'illegal' logging as a legal practice. Although the results suggest that 'illegal' logging has reduced as a result, the total rate of deforestation has in fact increased.

On the demand side, the timber demand in China did shift from domestic to import based, including that for illegal timber, due to the implementation of natural resource protection policies in the recent past. Whereas, domestic supply has increased due to a rapid implementation of afforestation and reforestation based projects. Therefore, the demand for imported illegal timber from Indonesia has declined as a consequence.

The number of new housing starts is found to be a significant driver of imports demand from Japan for illegal Indonesian timber. The Japanese building construction industry has become the largest consumer of wood products from illegal sources (Araya et al., 2008). Our analysis also suggests that the level of domestic timber supply in Japan has an important impact on the import of Indonesian illegally logged timber into the country.

We further find that law enforcement related activities in Indonesia, or policies with a law foundation, are significant factors that help reduce illegal logging. Since corruption is a key driver of illegal harvesting, the associated laws and related policies are effective in curbing illegal logging by catching grey money and preventing corruption. Finally, it is also worth noting the limitations of this study as pointed out earlier.

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Appendix A Descriptions and sources for variables in the model

Variables	Description	Units	Source
Q_J	Illegal timber imports in Japan	m^3	ITTO
$PLOG_J$	Round-log production in China	$1000m^3$	(Araya et al., 2008)
HS_J	Number of housing starts in Japan	Unit	Ministry of Land, Infrastructure, Transport and Tourism in Japan
Q_C	Illegal timber imports in China	m^3	ITTO
HS_C	Number of housing starts in China	Million m^2	Urban housing Markets in China (2009)
$PLOG_C$	Round-log production in China	$1000m^3$	National Bureau of Statistics of China
Q_I	Sum of illegal exports of Japan and China	m3	ITTO
P	Legal timber export price in Indonesia	$\$/m^3$	FAOSTAT
CI_I	Corruption Perception Index of Indonesia	Index	Transparency International
$INDIS_I$	Increase in number of districts in Indonesia	Number	(Burgess et al., 2012)
$PROAD_I$	Percentage of paved road on the total road in Indonesia	%	World Bank
GDP_I	Indonesian GDP (basic year is 2005)	US$	World Bank, CEIC
REGU	The ban of log exports first introduced from 1985 to 1997 and reintroduced in 2003(1-the policy has been introduced;0-no policy)	Binary variable	(Luttrell et al., 2011)
ANTIM	The anti-money laundering and anti-corruption law introduced in 2005(1-the policy has been introduced;0-no policy)	Binary variable	(Luttrell et al., 2011)
BIL	The bilateral agreements with timber-importing countries introduced in 2002 (1-the policy has been introduced;0-no policy)	Binary variable	(Luttrell et al., 2011)
$GREEN_J$	The item of 'legal wood' was added in the Green Purchasing Law by the Japanese government in 2006 (1-the policy has been introduced;0-no policy)	Binary variable	(MOE, 2007)

Appendix B Timber imports from Indonesia and Indonesian records of timber exports to US and UK from 1996 to 2010

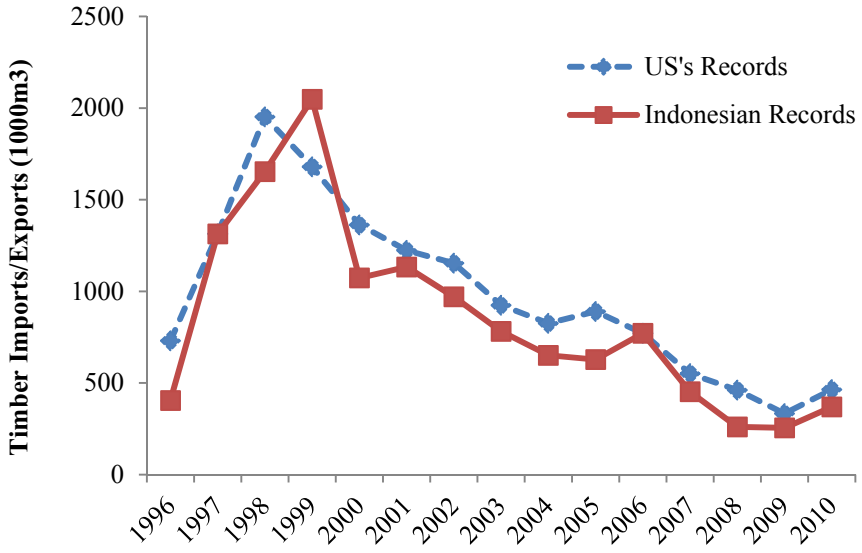

Fig. B.1. Discrepancy between US records of timber imports from Indonesia and Indonesian records of timber exports to US from 1996 to 2010

Source: ITTO (1997-2012)

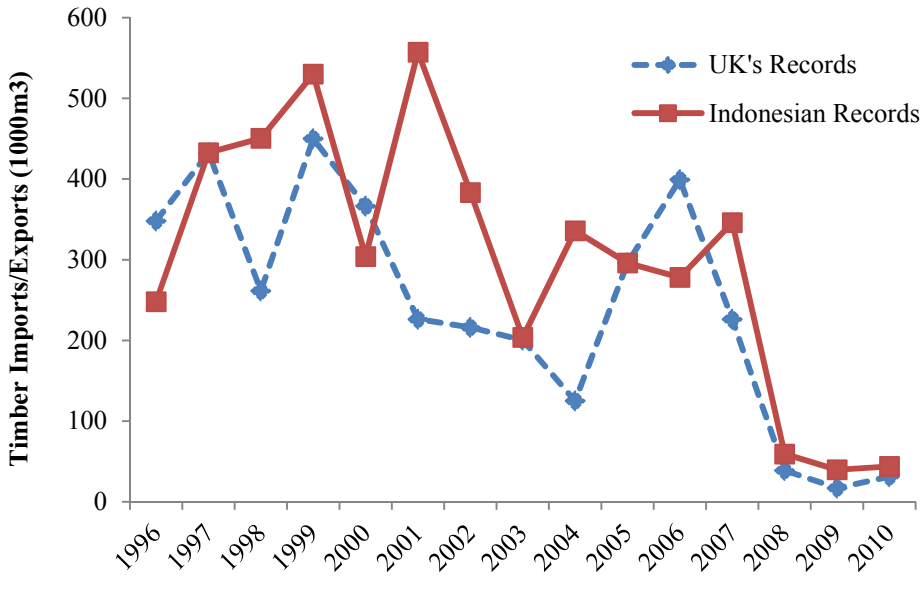

Fig. B.2. Discrepancy between UK records of timber imports from Indonesia and Indonesian records of timber exports to UK from 1996 to 2010

Source: ITTO (1997-2012)

FIGURES AND TABLES

Table 1 Results of the simultaneous-equation model

	Indonesia's supply Q_I	Japan's demand Q_J	Japan's demand Q_J	China's demand Q_C	China's demand Q_C
Methods	TSLS	TSLS	OLS	TSLS	OLS
constant	29.9526	-29.8480*	-26.9903	35.8619***	34.1234**
	(31.0909)	(16.2783)	(30.1302)	(10.2140)	(14.4987)
P	-	-	0.6408	-	0.2071
			(1.7674)		(1.1648)
Predicted P	-3.1778	0.800	-	0.0414	-
	(2.5229)	(0.8453)		(0.8952)	
$INDIS_I$	-0.4347*	-	-	-	-
	(0.2447)				
CI_I	-13.1539***	-	-	-	-
	(3.2322)				
$PROAD_I$	10.9773**				
	(4.4364)				
GDP_I	-0.4920	-	-	-	-
	(0.8325)				
HS_J	-	5.5056***	5.4644*	-	-
		(1.0202)	(1.6375)		
$PLOG_J$	-	-4.4033***	-4.3777***	-	-
		(1.5053)	(2.2124)		
HS_C	-	-	-	-0.2987	-0.2933
				(0.2300)	(0.3014)
$PLOG_C$	-	-	-	-1.8929***	-1.8974**
				(0.4172)	(0.7930)
Hausman test	Chi-square(1)= 3.1056 P value= 0.078	Chi-square(1)= 0.6343 P value= 0.4258	R-squared =0.5	Chi-square(1)= 0.7187 P value= 0.3966	R-squared =0.5
Weak instruments test	F-statistic= 136.115	F-statistic= 223.529		F-statistic= 215.23	
Sargan test	LM=5.6958 P value= 0.1274	LM=12.3755 P value= 0.03		LM=9.7882 P value= 0.0815	

Note: the asterisk*, **, *** denote significance at the 10%, 5% and 1% level.
Number in parentheses are standard errors.

Table 2 Results of Regulatory Influence on Illegal Trading in Indonesia

		Q_I	
constant	250.473***	174.829***	229.551***
	(91.7428)	(49.8416)	(47.8729)
predicted P	-19.2447**	-11.4108***	-15.5242***
	(7.9533)	(3.8996)	(3.8342)
GDP_I	-2.1299	-3.4888***	-4.9109***
	(1.5256)	(1.173)	(1.0303)
REGU	-5.6186**	-	-
	(2.3530)		
ANTIM	-	-3.8387***	-
		(0.8750)	
BIL	-	-	-4.6162***
			(0.8750)
Hausman test	Chi-square(1)= 5.5332 P value= 0.0187	Chi-square(1)= 8.6273 P value= 0.0033	Chi-square(1)= 7.1192 P value= 0.0076
Weak instruments test	F-statistic= 13.7354	F-statistic= 19.6667	F-statistic= 42.4932
Sargan test	LM=6.7727 P value= 0.2381	LM=2.7244 P value= 0.6050	LM=2.8579 P value= 0.5819

Note: the asterisks*, **, *** denote significance at the 10%, 5% and 1% level.
Number in parentheses are standard errors.

Table 3 Results of Regulatory influence on Illegal Demand in Japan and China

	Q_J	Q_J	Q_J	Q_J	Q_C	Q_C
Methods	TSLS	OLS	TSLS	OLS	TSLS	OLS
constant	0.2491	2.4257	61.0896**	65.5900	38.3482***	36.3421*
	(23.5207)	(30.2439)	(30.4033)	(38.878)	(12.4875)	(17.0971)
predicted P	0.5029	-	-1.528	-	-	-
	(0.8117)		(1.1632)			
P	-	0.3315	-	-1.7926	-0.1234	0.0558
		(1.5731)		(1.5969)	(1.0504)	(1.3306)
HS_J	2.8617*	2.8192	3.5425***	3.4605**	-	-
	(1.7124)	(1.9334)	(0.8665)	(1.4384)		
$PLOG_J$	-3.2523**	-3.2283	-8.1483***	-8.2285***	-	-
	(1.5102)	(2.0375)	(1.3894)	(2.1495)		
HS_C					-0.0540	-0.0900
					(0.4097)	(0.8004)
$PLOG_C$	-	-	-	-	-2.0778***	-2.0510***
					(0.4750)	(0.9952)
$GREEN_J$	-1.3095*	-1.316*	-	-	-	-
	(0.6927)	(0.6358)				
BIL			-1.9366***	-1.9877**	-0.3165	-0.2636
			(0.5562)	(0.6666)	(0.4393)	(0.9546)
Hausman test	Chi-square(1)= 0.4695 P value= 0.4932	R-squared= 0.4938	Chi-square(1)= 0.6290 P value= 0.4277	R-squared= 0.6111	Chi-square(1)= 0.5810 P value= 0.4459	R-squared= 0.4
Weak instruments test	F-statistic= 160.335		F-statistic= 160.26		F-statistic= 228.603	
Sargan test	LM=11.8283 P value= 0.0372		LM=11.8015 P value= 0.0376		LM=10.8348 P value= 0.0548	

Note: the asterisks*, **, *** denote significance at the 10%, 5% and 1% level.
Number in parentheses are standard errors.

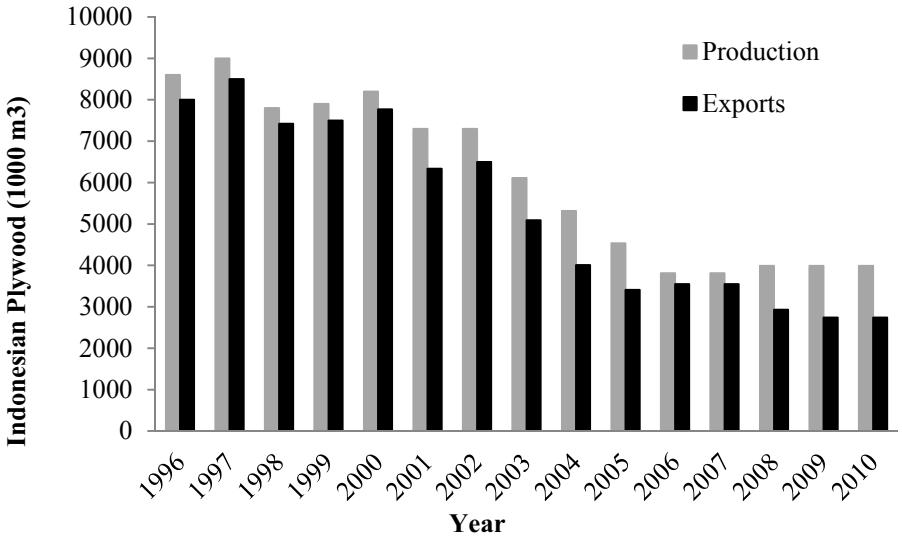

Fig.1. Indonesian plywood production and plywood exports between 1996 and 2010

Source: ITTO (1997-2012)

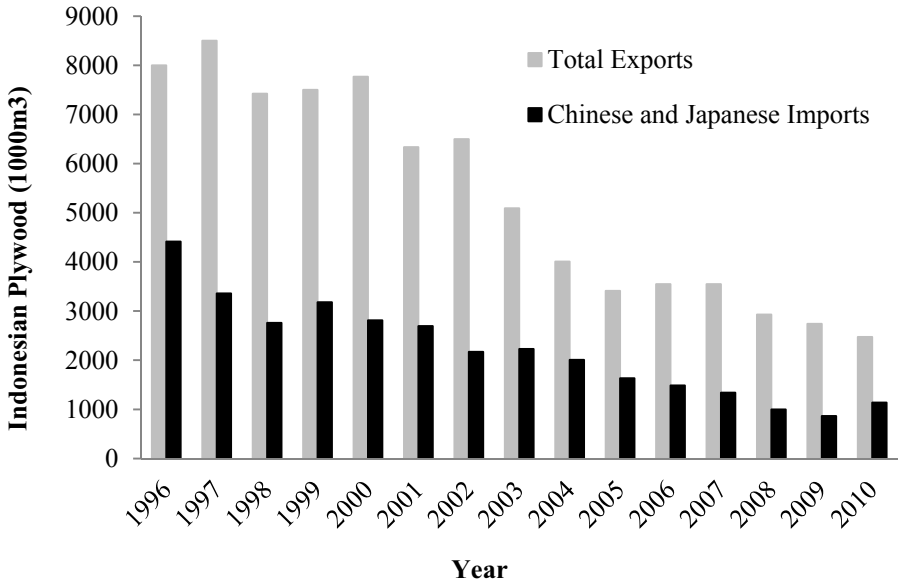

Fig.2. China and Japan plywood imports from Indonesia and Indonesian plywood exports from 1996 to 2010

Source: ITTO (1997-2012)

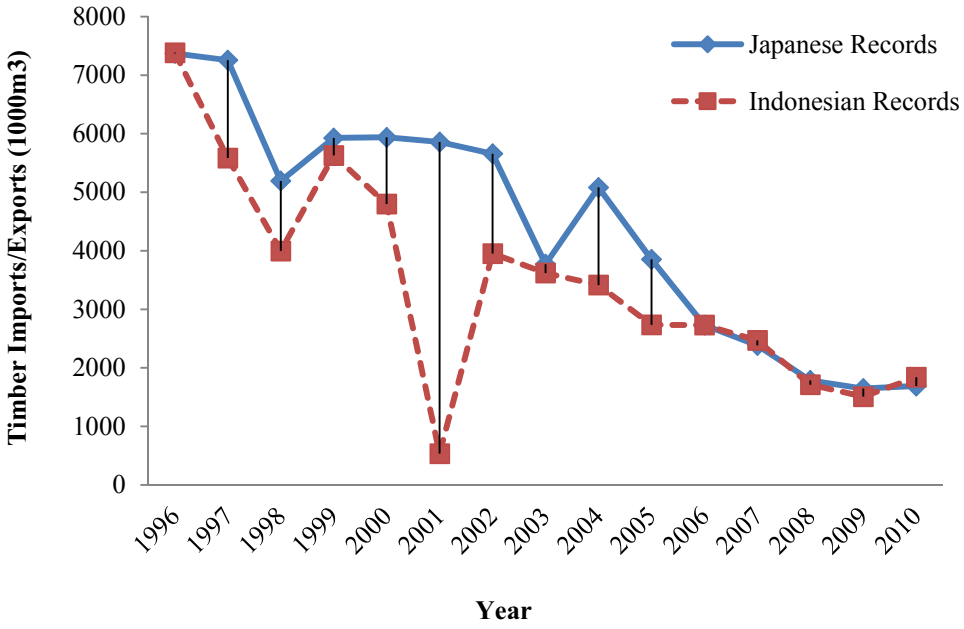

Fig.3. Discrepancy between Japanese records of timber imports from Indonesia and Indonesian records of timber exports to Japan from 1996 to 2010

Source: ITTO (1997-2012)

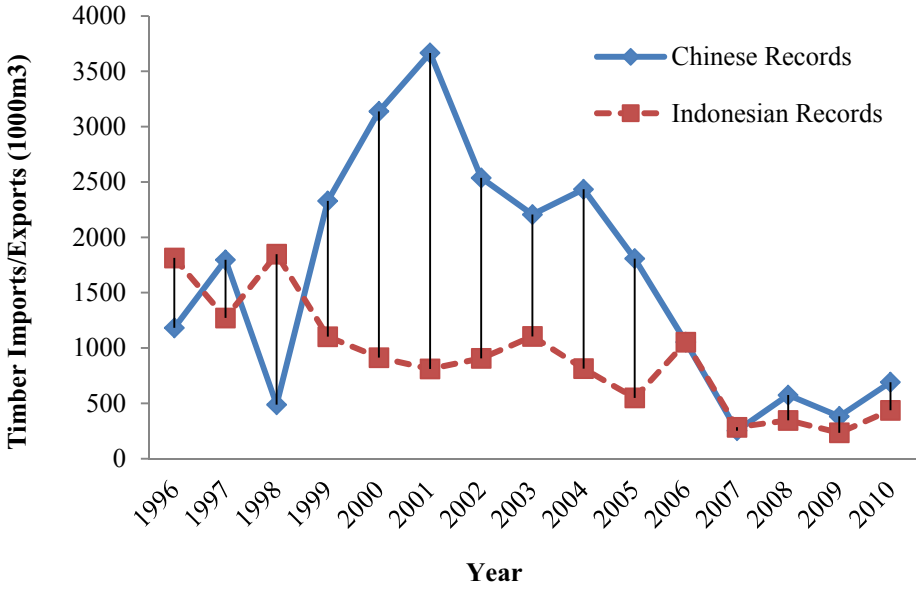

Fig.4. Discrepancy between Chinese records of timber imports from Indonesia and Indonesian records of timber exports to China from 1996 to 2010

Source: ITTO (1997-2012)

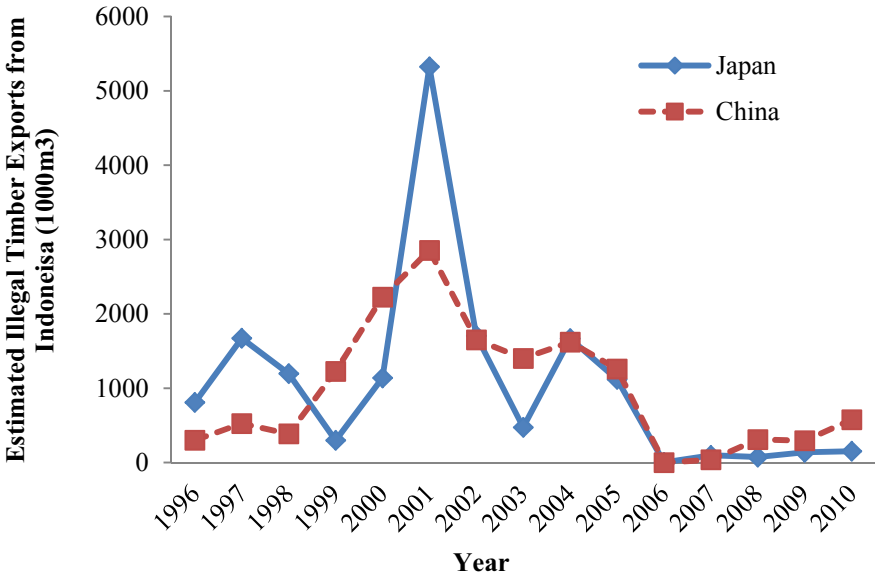

Fig.5. The estimated illegal timber exports from Indonesia to Japan and China from 1996 to 2010

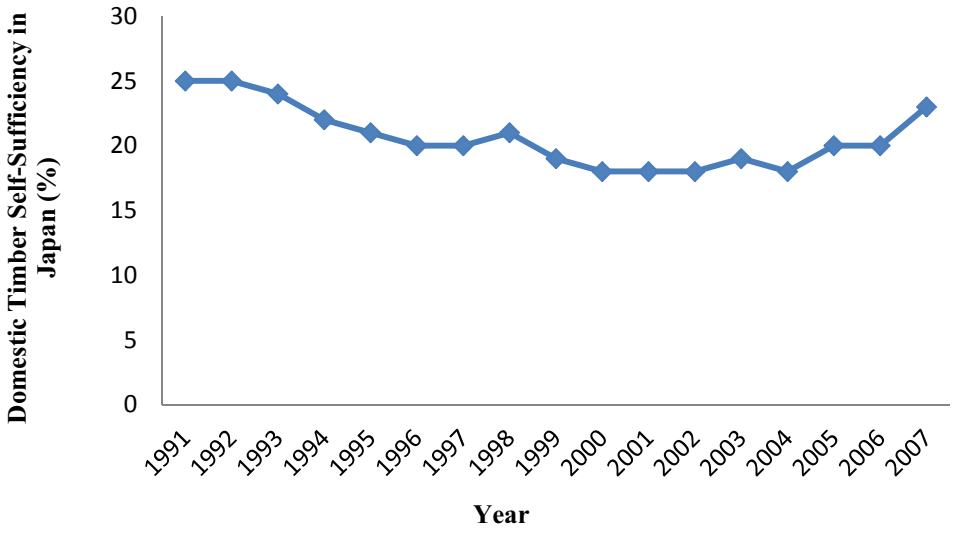

Fig.6. Domestic timber self-sufficiency percentages in Japan from 1991 to 2007

Source: (Araya et al. (2008))

Fig.7. Production of round log in China from 1996 to 2010

Source: National Bureau of Statistics of China

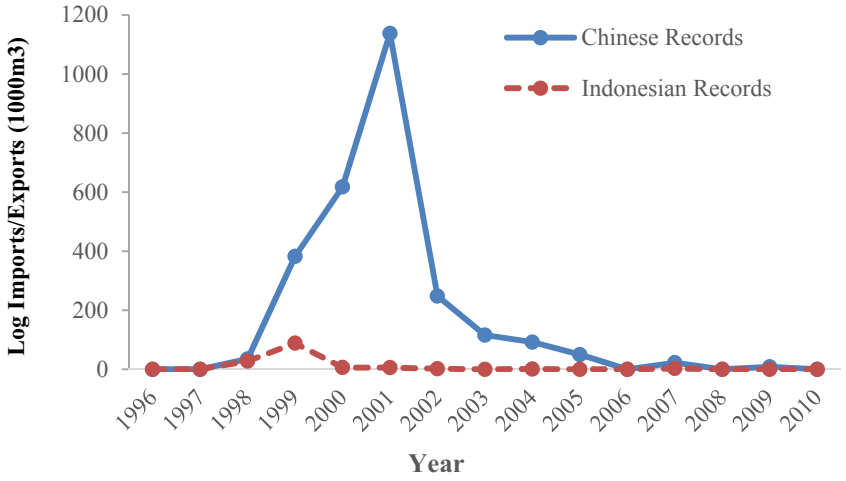

Fig.8. Chinese records of log imports from Indonesia and Indonesian records of log exports to China from 1996 to 2010

Source: ITTO (1997-2012)

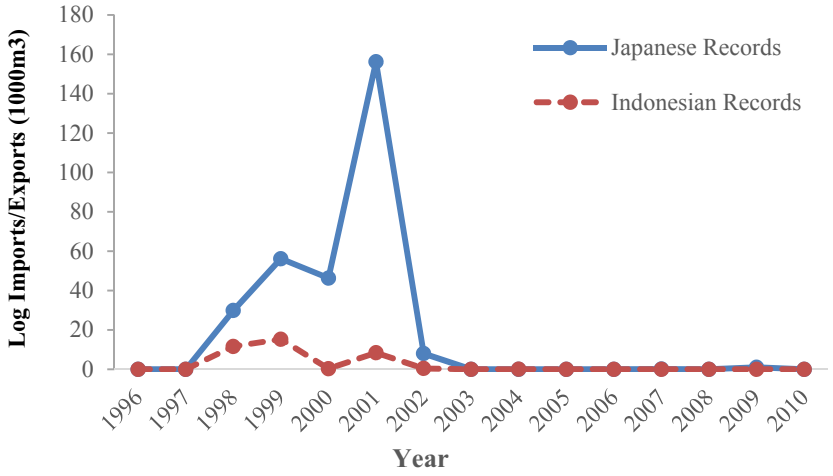

Fig.9. Japanese records of log imports from Indonesia and Indonesian records of log exports to Japan from 1996 to 2010

Source: ITTO (1997-2012)